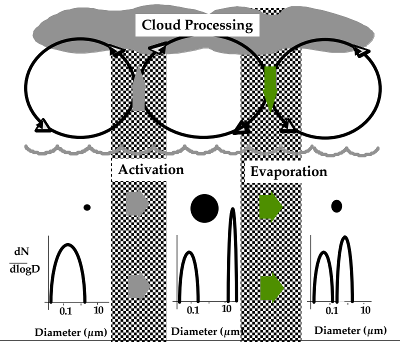
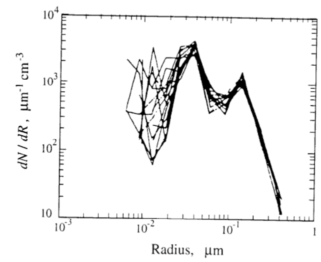
Cloud Condensation Nuclei



7.1

Hoppel Minimum

- Particle evolution in remote marine conditions
- **cloud processing** – growth of particles due to coalescence and solute condensation in cloud

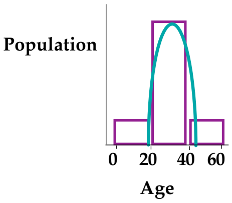


Seinfeld and Pandis, Fig. 15.23 (Hoppel et al., 1990)

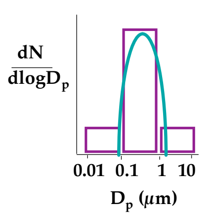
1.2

Number Distributions vs. Population Distributions

Human Population Age Distribution (Manhattan)

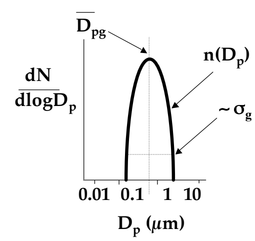


Aerosol Particle Size Distribution (Manhattan)



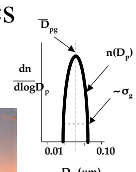
Particle Size Distributions

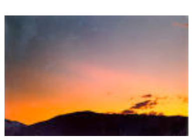
- Number concentration
  - Total number N
  - Differential number n
- Mean size
  - Geometric
  - Arithmetic
  - Number-based
  - Mass-based
- Size variability
  - Standard deviation σ
  - Geometric standard deviation σ_g

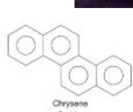


Particle Characteristics

- Concentration and size
- Chemical composition
- Light scattering

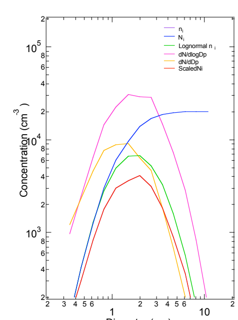




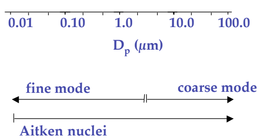


Size Characterization of Particles

- clusters of molecules
- starting at 100 molecules/cluster
- growth by condensation of molecules is nearly continuous
- multiple ways to graph same distribution

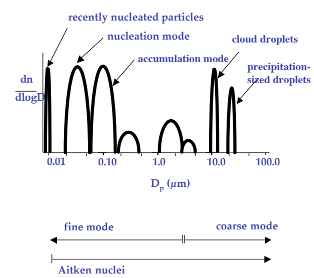


Particle Sizes



- range of particle sizes is approximately from 1 nm to 1 mm in diameter
- range of approximately 6 orders of magnitude
- concentrations at each of these sizes also vary

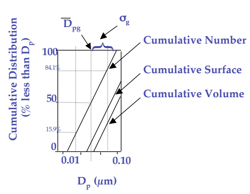
Size Distribution Modes

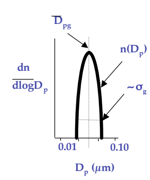


- modes of aerosol are distinguished by
  - size
  - sources
  - behavior

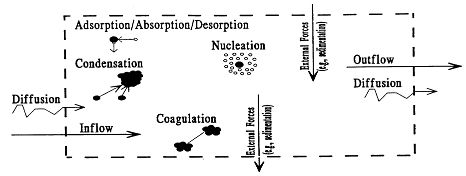
Log-Normal Number Distributions

- Cumulative
- Differential



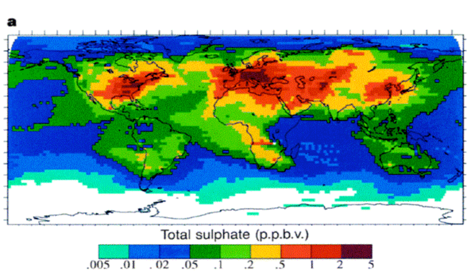


Microphysics



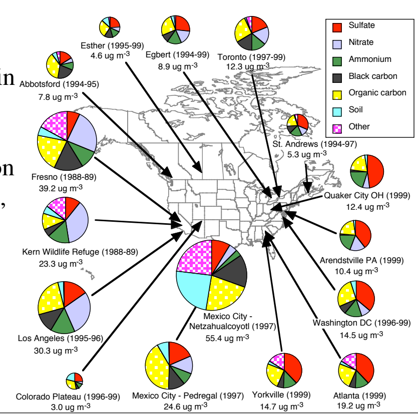
- Aerosol includes both particles and vapor
- Number, area, volume, mass vary nonlinearly
- Deposition velocity depends on size (nano, micro, milli)
- Scavenging, coalescence, activation and condensation change the size distribution

Global Aerosol Distribution



Capaldo et al., *Nature*, 1999

- Regional variations in aerosol mass and composition [NARSTO, 2002]



ROAST Reviews

- Review comments due to editor: Nov. 6
  - Reviews are completed by individuals not groups.
  - Reviewer's name should **not** appear in review.
  - Reviewer's name should be in filename.
    - "GroupAp1v1reviewLASTNAME.pdf"
- http://www.elsevier.com/wps/find/editorsinfo.editors/ebu/issue5a

Homework Ch. 5 Prob. 3

$$r^* = \sqrt{\frac{3b}{a}}$$

$$S^* = 1 + \sqrt{\frac{4a^3}{27b}}$$

$$a = 2\sigma_{lv} / (\rho_l R_v T).$$

$$b = 3 i M_v \frac{m_{solt}}{4\pi M_{solt} \rho_l}$$

rho_l	1000	kg/m3	
sigma_lv	0.075015	N/m	Eqn. 5.7
Rv	461.478686	J/K/KG	
T	280	K	
I	2		
M_v	18.016	g/mol	
M_sol	132.1	g/mol	
m_sol	1.00E-18	KG	
a	1.1611E-09	m	a=2sigma/(rho*Rv*T)
b	6.5117E-23	m3	b=3i*Mv*msol/(4pi*Msol*rho)
r*	4.1018E-07	m	r*=sqrt(3b/a)
S*	1.00188713		S*=1+sqrt(4a^3/27b)

Example Ch. 5 Prob. 7

Curry and Webster, p. 158, Problem 7a-c

7. An analytic expression of the following form has been used to describe drop size spectra:

$$n(r) = Ar^2 \exp(-Br)$$

where A and B are parameters. For a drop size spectrum represented by this relationship, determine the following:

a) the total drop concentration per volume of air:

$$N = \int_0^\infty n(r)\,dr$$

b) the mean drop radius:

$$\bar{r} = \frac{1}{N}\int_0^\infty r\,n(r)\,dr$$

c) the coefficients A and B for $N = 200$ cm^{-3} and $\bar{r} = 10\ \mu$m;

Integral Tables (521), CRC 1986 p. 330

$$\int x^m e^{ax} dx = \frac{x^m e^{ax}}{a} - \frac{m}{a}\int x^{m-1} e^{ax} dx = e^{ax}\sum_{r=0}^{m} (-1)^r \frac{m!\,x^{m-r}}{(m-r)!\,a^{r+1}}$$

Example Ch. 5 Prob. 7

a) the total drop concentration per volume of air:

$$n(r) = Ar^2 \exp(-Br)$$

$$N = \int_0^\infty n(r)\,dr$$

$$N = \int_0^\infty Ar^2 e^{-Br} dr$$

$$= A\frac{e^{-Br}}{-B}\left(r^2 - \frac{2}{B^2}(-Br-1)\right)\Bigg|_0^\infty$$

$$= 0 - \left[-\frac{A}{B}\left(\frac{2}{B^2}\right)\right]$$

$$= \frac{2A}{B^3}$$

Integral Tables (521)
CRC 1986 p. 330

$$\int x^m e^{ax} dx = e^{ax}\sum_{r=0}^{m} (-1)^r \frac{m!\,x^{m-r}}{(m-r)!\,a^{r+1}}$$

$$\int x^2 e^{ax} dx = \frac{e^{ax}}{a}\left(x^2 - \frac{2}{a^2}(ax-1)\right)$$

Example Ch. 5 Prob. 7

b) the mean drop radius:

$$n(r) = Ar^2 \exp(-Br)$$

$$\bar{r} = \frac{1}{N}\int_0^\infty r\,n(r)\,dr$$

$$\bar{r} = \frac{1}{N}\int_0^\infty Ar^3 e^{-Br} dr$$

$$= \frac{A}{N}\left(\frac{e^{-Br}}{-B}\right)\left(r^3 + \frac{3r^2}{B} - \frac{6}{B^3}(-Br-1)\right)\Bigg|_0^\infty$$

$$= 0 - \left[-\frac{A}{BN}\left(\frac{6}{B^3}\right)\right]$$

$$= \frac{3}{B}$$

Integral Tables (521)
CRC 1986 p. 330

$$\int x^m e^{ax} dx = e^{ax}\sum_{r=0}^{m} (-1)^r \frac{m!\,x^{m-r}}{(m-r)!\,a^{r+1}}$$

$$\int x^3 e^{ax} dx = \frac{e^{ax}}{a}\left(x^3 - \frac{3x^2}{a} + \frac{6}{a^3}(ax-1)\right)$$

Example Ch. 5 Prob. 7

c) the coefficients A and B for $N = 200$ cm^{-3} and $\bar{r} = 10\ \mu$m;

$$\bar{r} = \frac{3}{B} = 10 \times 10^{-6}$$

$$B = 3 \times 10^5$$

$$N = \frac{2A}{B^3} = 200 \times 10^6$$

$$A = 2.7 \times 10^{24}$$

Example Ch. 5 Prob. 7

d) the liquid water mixing ratio, w_l:

$$n(r) = Ar^2 \exp(-Br)$$

$$w_l = \frac{\rho_l}{\rho_a}\frac{4}{3}p\int_0^\infty r\,n(r)\,dr$$

Integral Tables (521)
CRC 1986 p. 330

$$\int x^m e^{ax}dx = e^{ax}\sum_{r=0}^{m}(-1)^r \frac{m!x^{m-r}}{(m-r)!a^{r+1}}$$

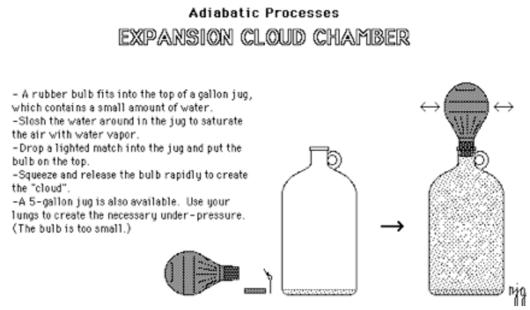
$$= 120e^{ax}\left(\frac{x^5}{120a} - \frac{x^4}{24a^2} + \frac{x^3}{6a^3} - \frac{x^2}{2a^4} + \frac{x}{a^5} - \frac{1}{a^6}\right)$$

$$w_l = \left(\frac{4\pi A\rho_l}{3\rho_a}\right)\int r^5 e^{-Br}dr$$

$$= \left(\frac{4\pi A\rho_l}{3\rho_a}\right)120e^{-Br}\left(\frac{r^5}{-120B} - \frac{r^4}{24B^2} + \frac{r^3}{-6B^3} - \frac{r^2}{2B^4} + \frac{r}{-B^5} - \frac{1}{B^6}\right)\Bigg|_0^\infty$$

$$= \left(\frac{4\pi A\rho_l}{3\rho_a}\right)\left(0 - \frac{-120}{B^6}\right) = \left(\frac{160\pi A\rho_l}{B^6\rho_a}\right)$$

Cloud in a Jar Demonstration



http://groups.physics.umn.edu/demo/old_page/demo_gifs/4B70_20.GIF

Lecture Ch. 6a

100%. For simplicity, we assume here that clouds form in the atmosphere when the water vapor reaches its saturation value and $\mathcal{H}$= 100%.

- Saturation of moist air
- Relationship between humidity and dewpoint
  - Clausius-Clapeyron equation
- Dewpoint
  - Temperature
  - Depression
- Isobaric cooling

Curry and Webster, Ch. 6
For Tuesday: Read Ch. 7

How does saturation occur?

- By increasing water vapor
  - Evaporation of water at surface
  - Evaporation of falling rain
- By cooling
  - Isobaric
  - Radiative cooling of rising air
- By mixing of two unsaturated air parcels

Curry and Webster, Ch. 6

Saturation of Moist Air

- Dew point temperature

The temperature at which saturation is reached in an isobaric cooling process is the ***dew-point temperature***, which is illustrated in Figure 6.1a. The dew-point temperature, denoted by T_D, can be defined by

$$e = e_s(T_D) \qquad (6.14)$$

or equivalently by

$$w_v = w_s(T_D) \qquad (6.15)$$

Curry and Webster, Ch. 6

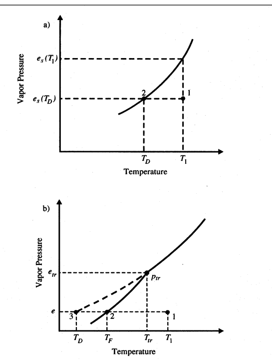


Figure 6.1 a) Relationship between temperature and vapor pressure in an isobaric cooling process. Air initially at temperature T_1 (point 1) is cooled isobarically until it reaches saturation (point 2). The temperature at point 2 defines the dew-point temperature, T_D. b) Air at T_1 (point 1) cools isobarically until it reaches saturation. If the saturation is reached with respect to ice (point 2), the temperature is called the frost point, T_F.